Clinical Features of Children With Autism Who Passed 18-Month Screening

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abstract

OBJECTIVES: We compared sex-stratified developmental and temperamental profiles at 18 months in children screening negative for autism spectrum disorder (ASD) on the Modified Checklist for Autism in Toddlers (M-CHAT) but later receiving diagnoses of ASD (false-negative group) versus those without later ASD diagnoses (true-negative group).

METHODS: We included 68 197 screen-negative cases from the Norwegian Mother and Child Cohort Study (49.1% girls). Children were screened by using the 6 critical items of the M-CHAT at 18 months. Groups were compared on domains of the Ages and Stages Questionnaire and the Emotionality Activity Sociability Temperament Survey.

RESULTS: Despite passing M-CHAT screening at 18 months, children in the false-negative group exhibited delays in social, communication, and motor skills compared with the true-negative group. Differences were more pronounced in girls. However, with regard to shyness, boys in the false-negative group were rated as more shy than their true-negative counterparts, but girls in the false-negative group were rated as less shy than their counterparts in the true-negative group.

CONCLUSIONS: This is the first study to reveal that children who pass M-CHAT screening at 18 months and are later diagnosed with ASD exhibit delays in core social and communication areas as well as fine motor skills at 18 months. Differences appeared to be more pronounced in girls. With these findings, we underscore the need to enhance the understanding of early markers of ASD in boys and girls, as well as factors affecting parental report on early delays and abnormalities, to improve the sensitivity of screening instruments.

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WHAT'S KNOWN ON THIS SUBJECT: To our best knowledge, no researchers have examined the clinical characteristics of children who pass screening for autism spectrum disorder (ASD) at 18 months but are later diagnosed with the disorder.

WHAT THIS STUDY ADDS: The current study reveals that despite passing screening for ASD, 18-month-old boys and girls who are later diagnosed with ASD show delays and atypical features in social, communication, and motor domains at the time of the screening.

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The primary goal of autism spectrum disorder (ASD) screening instruments is to facilitate the early identification and implementation of early interventions. However, because most studies are conducted in clinical populations, it is unclear if existing screening instruments have sufficiently high sensitivity, specificity, and positive predictive value (PPV) in general population-based samples.[1,2] Furthermore, there is increasing awareness of substantial heterogeneity with respect to both the timing of the onset of recognizable symptoms[3] and patterns of symptom expression.[4] Recognizing that symptoms of ASD may become apparent at different ages as social demands begin to exceed a child's limitations, the strict age-of-onset criterion in previous formal definitions of ASD has been removed from the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition*.[5] Moreover, recent prospective studies of infants who are at familial risk for ASD reveal that symptoms of ASD may manifest somewhat differently depending on a child's verbal and nonverbal levels of functioning.[6]

The Modified Checklist for Autism in Toddlers (M-CHAT)[7] is the most widely used screening instrument for ASD in young children.[8] Designed to be completed in the waiting room of a primary care provider,[7] it has been recommended for use in toddlers at 18 months of age with a follow-up at 24 months.[9] Although studies of the M-CHAT typically reveal its high sensitivity in clinical samples, it has been criticized for its lower specificity and PPV. In an unselected population sample, Stenberg et al[10] reported a PPV of 3.3% using the M-CHAT's 6-critical-item criterion and 1.5% using the total 23-item criterion in a general population sample. In selected populations (ie, children with developmental concerns), the M-CHAT performs better in detecting children who are at risk for ASD.[7,11,12] A critical gap in the current evidence stems from a lack of prospective follow-up studies of children who screen negative.[1]

To the best of our knowledge, no researchers have yet investigated the developmental and temperamental characteristics of children who screen negative on the basis of the M-CHAT at 18 months of age but later receive an ASD diagnosis. Understanding how early symptoms manifest in this group of children is of paramount significance for the development of future ASD-specific screening instruments. There are multiple reasons why a child with ASD may pass early screening only to be diagnosed with ASD later in childhood, apart from simply experiencing later symptom onset. Limited parental knowledge or understanding of the screening questions may also be an issue, although recent studies have revealed good agreement between parents and clinicians on ratings of autism-related behaviors among the parents of infants who are at risk for ASD.[13,14] Studies also reveal that child-related factors such as better developed language,[15] the absence of repetitive and restricted behaviors, average-range IQ, younger age at assessment,[16,17] and lack of additional behavioral issues[18] may mask symptoms of social disability. Incorporating other measures that can be used to more broadly examine developmental features and consider children's developmental levels could provide new insights with regard to earlier identification of children with ASD. Moreover, given multiple reports revealing sex differences in syndrome expression,[19–23] there is great need to evaluate the performance of existing screens in both boys and girls.

In the current study, we examined developmental and temperamental characteristics of children who passed the 6-critical-item criterion of the M-CHAT at 18 months but went on to receive an ASD diagnosis. Specifically, we compared screen-negative children without a later ASD diagnosis (true-negative group) to screen-negative children with a later ASD diagnosis (false-negative group) on a set of developmental and temperamental features that were also measured at age 18 months. We capitalized on data collected through the Norwegian Mother and Child Cohort Study (MoBa),[24] which is a prospective, countrywide pregnancy cohort of parents who were recruited at the 18th gestational week ultrasound examination and were managed regularly with questionnaires related to child development. The M-CHAT,[7] along with other developmental scales, was part of the 18-month MoBa questionnaire. The examination of characteristics in screen-negative children may facilitate the identification of new behavioral markers of ASD at critical time points for the emergence of frank behavioral symptoms of ASD.

METHODS

Study Population

The study sample is derived from the MoBa.[24] In total, 40.6% of invited mothers consented to participate. Diagnoses of ASD were obtained from the Autism Birth Cohort (ABC), which is a substudy in the MoBa[25] in which researchers integrated diagnoses from ABC clinic assessments at child age 40 months and older and diagnoses obtained through annual linkage with the Norwegian Patient Registry (NPR). The NPR is a national database of all discharge diagnoses of patients who are assessed in health care services across Norway. It has been available since 2008. According to national guidelines for specialist health care in Norway, the use of the Autism Diagnostic

Observation Schedule and Autism Diagnostic Interview-Revised in the diagnostic process is mandatory, together with a range of other tests and/or interviews related to cognitive and adaptive function. The researchers in the MoBa and ABC study obtained written, informed consent from participating mothers and were granted approval from the Norwegian Data Inspectorate as well as the Regional Committees for Medical and Health Research Ethics, Southeast Norway. In the current study, we used the MoBa data release version 9, reflecting diagnoses collected throughout 2015 (Fig 1).

Measures

MoBa questionnaires completed when the child was 18 months old included the M-CHAT, selected items from the Ages and Stages Questionnaire (ASQ)[26] and the Emotionality Activity Sociability Temperament Survey (EAS).[27] The M-CHAT is a 23-item screening instrument,[7] with each item scored either as pass or fail. Six of the 23 items are considered critical for predicting an ASD diagnosis[7] because the items probe for social and communicative behaviors such as pointing, interest in other children, imitation, and response to his or her own name (Supplemental Information).

Children are considered to have screened positive if they fail ≥2 of the 6 critical items. For the purpose of this study, individual scores on the 6 critical items were summarized, and children receiving scores <2 were categorized as having screened negative. The focus on the 6 critical items was motivated by findings that this criterion provides the best precision for predicting ASD.[7,10,11,28] The means of the 6 critical items are listed in Table 1.

The ASQ is a parent-reported questionnaire designed to measure developmental skills from ages

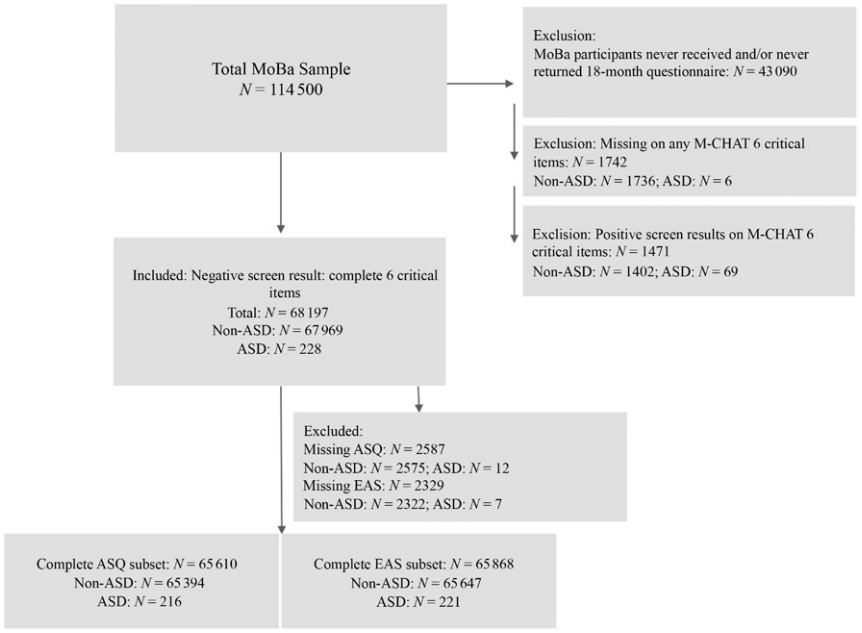

FIGURE 1
Sample inclusion and exclusion information.

TABLE 1 Number of Cases and Mean (SD) of Participant's Age at Time of Screening and of Failed M-CHAT 6 Critical Items

	Total True-Negative Cases	True-Negative Boys	True-Negative Girls	Total False-Negative Cases	False-Negative Boys	False-Negative Girls
No. cases	67 969	34 502	33 467	228	192	36
Age at time of screening, mo	18.53 (0.62)	18.53 (0.64)	18.53 (0.60)	18.51 (0.55)	18.51 (0.56)	18.53 (0.48)
Failed M-CHAT 6 critical items	0.10 (0.30)	0.12 (0.32)	0.08 (0.28)	0.27 (0.44)	0.25 (0.43)	0.41 (0.50)

4 months to 5 years.[26] For each item, parents are asked to rate whether specific behaviors are currently present: "yes" (10), present "sometimes" (5), and "not yet" present (0). Thus, a higher score indicates more normative development. A subset of 13 items falling into 4 ASQ-defined domains (social, communication, fine motor, and gross motor) were included in the MoBa 18-month questionnaire (Supplemental Figure 3).

The EAS[27] was designed for children aged 1 to 9 years and measures emotionality, activity, sociability, and shyness. For each item, the parent is asked to rate his or her child on a 5-point rating scale (from 1 [very characteristic and/or typical of your child] to 5 [not characteristic and/or typical of your child]). A subset of 11 items of the EAS[29] falling into 4 EAS-defined domains (sociability, shyness, activity, and emotionality) were included in the MoBa 18-month questionnaire (Supplemental Figure 4). Items were coded such that a higher score on all domains indicated more sociable and active traits and less shy and emotional traits.

Statistical Analyses

To compare children in the true-negative group to children in the false-negative group, we conducted a set of univariate analyses of variance

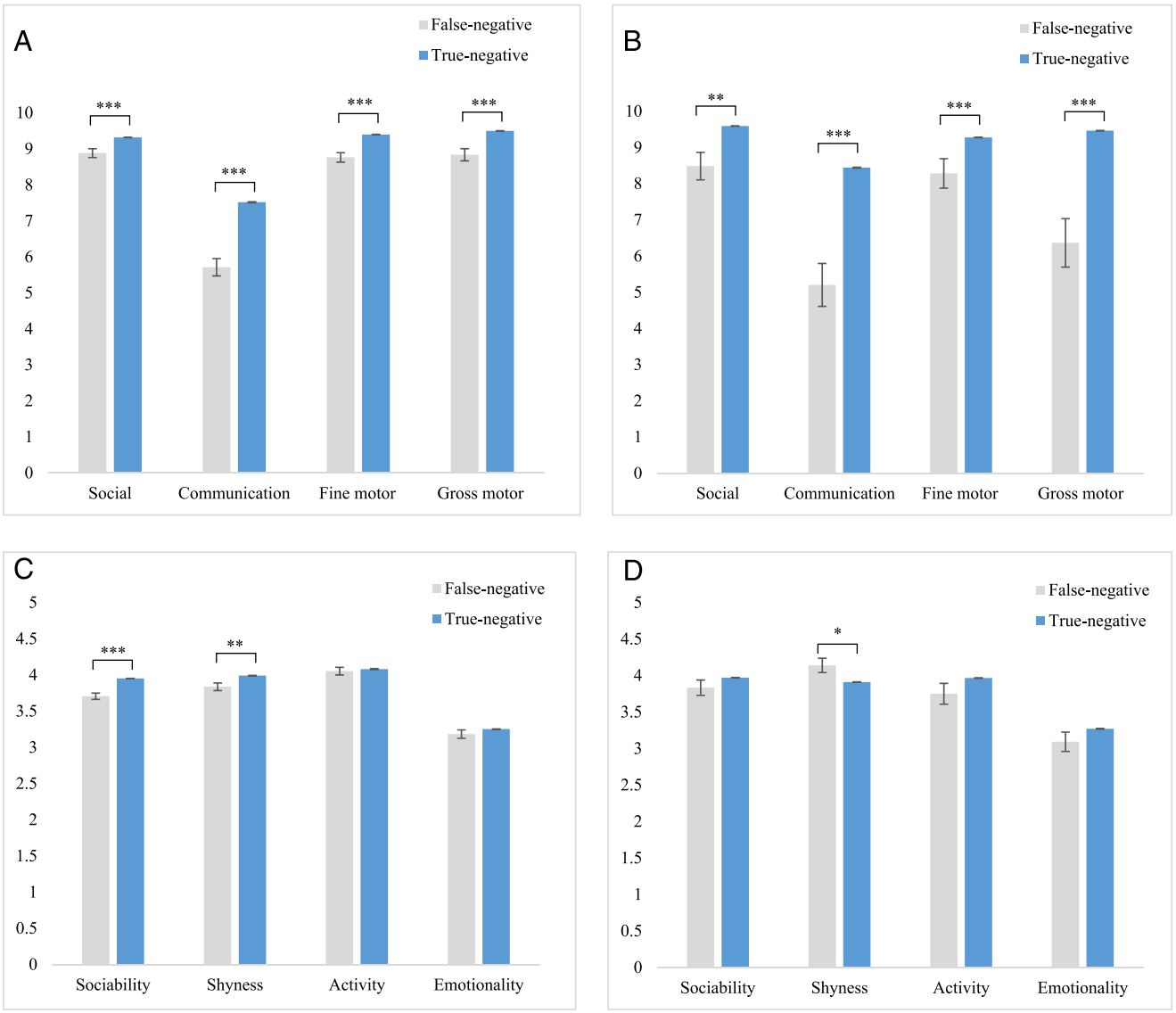

FIGURE 2

A, Mean (±1 SE) of the ASQ scores for false-negative and true-negative boys. *** $P < .001$. B, Mean (± 1 SE) of the ASQ scores for false-negative and true-negative girls. *** $P < .001$; ** $P < .010$. C, Mean (±1 SE) of the EAS scores for false-negative and true-negative boys. *** $P < .001$; ** $P < .010$. Higher scores on the shyness and emotionality scales indicate less shy and emotional presentation; higher sociability and activity scores indicate more pronounced characteristics in this domain. D, Mean (±1 SE) of the EAS scores for false-negative and true-negative girls. * $P < .050$. Higher scores on the shyness and emotionality scales indicate less shy and emotional presentation; higher sociability and activity scores indicate more pronounced characteristics in this domain.

with diagnosis (ASD and no ASD) and sex (male and female) as between-group factors on the ASQ and EAS domain scores. Post hoc analyses were conducted for between- and within-group differences by using independent samples. Analyses in which we compared true-positive to false-negative results are attached (Supplemental Figure 5). Bonferroni correction was used to control for multiple comparisons, and Cohen's *d* provided a measure of effect sizes in the independent samples analyses. Cohen's *d* was interpreted as follows: T (trivial), S (small), M (moderate), and L (large).[30]

RESULTS

Of the 69 668 children with all 6 critical items completed at the 18-month screening, 1471 screened positive and 68 197 screened negative. Among those screening negative, 49.1% were girls. Of the 68 197 screen-negative children, 228 (15.8% girls) were later diagnosed with ASD (false-negative children; Figs 2A and 2B).

Developmental Domains (ASQ)

Social Domain

Analyses revealed a significant effect of diagnosis ($P < .001$), no effect

TABLE 2 Mean (SD) of the ASQ Scores for Boys and Girls in the True-Negative and False-Negative Groups

	N	ASQ Social	ASQ Communication	ASQ Fine Motor	ASQ Gross Motor
Boys: true-negative	33 163	9.32 (1.18)	7.51 (2.64)	9.39 (1.27)	9.49 (1.40)
Girls: true-negative	32 231	9.59 (0.94)	8.44 (2.21)	9.28 (1.37)	9.46 (1.49)
Boys: false-negative	183	8.88 (1.66)	5.71 (3.26)	8.76 (1.78)	8.83 (2.29)
Girls: false-negative	33	8.48 (2.18)	5.20 (3.40)	8.28 (2.34)	6.36 (3.85)

TABLE 3 Mean (SD) of the EAS Scores for Boys and Girls in the True-Negative and False-Negative Groups

	N	EAS Sociability	EAS Shyness	EAS Emotionality	EAS Activity
Boys: true-negative	33 300	3.95 (0.55)	3.99 (0.62)	3.25 (0.75)	4.08 (0.64)
Girls: true-negative	32 347	3.96 (0.55)	3.91 (0.65)	3.27 (0.76)	3.96 (0.64)
Boys: false-negative	185	3.96 (0.59)	3.84 (0.71)	3.18 (0.79)	4.05 (0.71)
Girls: false-negative	36	3.83 (0.63)	4.14 (0.59)	3.09 (0.79)	3.75 (0.86)

Higher scores on the shyness and emotionality scales indicate less shy and emotional presentation; higher sociability and activity scores indicate more pronounced characteristics in this domain.

of sex ($P = .551$), and a significant diagnosis-by-sex interaction ($P = .001$; Table 2). Boys in the false-negative group were rated as less social than true-negative boys ($P < .001$; $d = 0.303$[S]). Girls in the false-negative group were also rated as having fewer social skills than true-negative girls ($P = .007$; $d = 0.657$[M]), but the magnitude of the difference was larger than that observed in boys. No significant differences were found between boys and girls in the false-negative group ($P = .329$; $d = 0.203$[S]). However, true-negative girls had higher scores on social skills than true-negative boys ($P < .001$; $d = 0.255$[S]).

Communication Domain

Analyses revealed a significant effect of diagnosis ($P < .001$), no effect of sex ($P = .366$), and a diagnosis-by-sex interaction ($P = .002$). There was a difference between the false-negative and true-negative boys in communication skills ($P < .001$; $d = 0.608$[M]) as well as between the false-negative and true-negative girls ($P < .001$; $d = 1.13$[L]). The magnitude of the effect was greater in girls. No differences were found between boys and girls in the false-negative groups ($P = .414$; $d = 0.152$[T]), but true-negative girls scored higher than true-negative boys ($P < .001$; $d = 0.380$[S]).

Fine Motor Domain

Analyses revealed significant effects of diagnosis ($P < .001$) and sex ($P = .017$) but no interaction between the factors ($P = .152$). Children in the false-negative group had, in general, less developed fine motor skills than children in the true-negative group ($P < .001$; $d = 0.399$[S]). Girls were generally less advanced in fine motor skills than boys ($P < .001$; $d = 0.088$[T]) regardless of diagnosis.

Gross Motor Domain

Analyses revealed significant effects of diagnosis ($P < .001$) and sex ($P < .001$) and a diagnosis-by-sex interaction ($P < .001$). There was a differences between the false-negative and true-negative boys in gross motor skills ($P < .001$; $d = 0.267$[S]) as well as between the false-negative and true-negative girls ($P < .001$; $d = 1.06$[L]). The magnitude of the effect was greater in girls. Girls in the false-negative group had lower scores than boys in the false-negative group ($P = .001$; $d = 0.779$[M]), and true-negative girls had lower scores than true-negative boys ($P = .005$; $d = 0.022$[T]; Figs 2C and 2D).

Temperamental Characteristics (EAS Subdomains)

Sociability

Analyses revealed a significant effect of diagnosis ($P < .001$), no effect of sex ($P = .156$), and no interaction effect ($P = .260$; Table 3). Post hoc analyses revealed that children in the false-negative group were rated as less sociable than children in the true-negative group regardless of their sex ($P < .001$; d = 0.403[S]).

Shyness

Analyses revealed no effects of diagnosis ($P = .551$) or sex ($P = .060$) but a significant diagnosis-by-sex interaction ($P = .001$). Post hoc analyses revealed that boys in the false-negative group were rated as more shy than boys in the true-negative group ($P = .003$; $d = 0.238$[S]). Girls in the false-negative group were rated as less shy than girls in the true-negative group ($P = .035$; $d = 0.369$[S]). Girls in the false-negative group were rated as less shy than boys in the false-negative group ($P = .017$; $d = 0.463$[S]). Furthermore, girls in the true-negative group were rated as more shy than boys in the true-negative group ($P < .001$; $d = 0.134$[T]).

Emotionality

Analyses revealed no significant effects of diagnosis ($P = .069$), sex

(P = .607), or interaction between diagnosis and sex (P = .435).

Activity

Analyses revealed significant effects of diagnosis (P = .036) and sex (P < .001) but no interaction effects (P = .114). Post hoc analyses revealed no difference between children in the false-negative and true-negative groups (P = .664). Girls were, in general, less active than boys (P < .001; d = 0.183[T]) regardless of diagnosis.

DISCUSSION

To the best of our knowledge, this study is the first in which researchers investigate the concurrent developmental and temperamental characteristics of boys and girls who pass the 6-critical-item criterion of the M-CHAT at 18 months of age but ultimately receive an ASD diagnosis at a later age. Using a large prospective population study, we compared children with false-negative screen results to true-negative children on their characteristics as measured concurrently with M-CHAT screening at 18 months.

Despite screening negative for ASD on the M-CHAT, children in the false-negative group exhibited delays and atypical features compared with children in the true-negative group. Specifically, children in the false-negative group were already rated by their parents at 18 months as having less developed social and communication skills as well as showing fine and gross motor delays compared with children in the true-negative group. The domains of impairment identified in the current study map onto those found in children with autism diagnosed in the second year of life,[6,31] revealing that atypical features in the false-negative cases may already be present at 18 months. There were no marked differences between boys and girls because in most cases, both boys and girls in the false-negative group performed poorer than their sex-matched counterparts in the true-negative group. However, the observed differences, as indexed by effect sizes, appeared more pronounced in girls, particularly in the social, communication, and gross motor domains. There was only 1 area in which boys and girls showed a different pattern: boys in the false-negative group were rated as more shy than boys in the true-negative group, whereas girls in the false-negative group were rated as less shy than girls in the true-negative group. These findings reveal that at 18 months, there are already nuanced differences in temperamental indices between boys and girls who screen negative and later receive an ASD diagnosis.

Intriguingly, girls in the false-negative group were rated as less socially inhibited compared with boys. This is in contrast to the pattern found in the true-negative group. A closer inspection of the shyness domain revealed that girls in the false-negative group had shorter warm-up time and appeared friendlier toward strangers than boys in the false-negative group (Supplemental Figure 3). We hypothesize that girls in the false-negative group have somewhat lower levels of social fearfulness or lower inhibitory control compared with boys. Studies have revealed that in typically developing children, girls show greater inhibitory control compared with boys.[32] The sparse research on inhibitory control in individuals with ASD also reveals that girls with ASD express less inhibition,[33,34] and there is a lack of knowledge about sex differences in fearfulness among young children with ASD. Future researchers should examine the levels of social fearfulness and inhibitory control during infancy and early childhood in ASD because these processes have a great capacity to shape the emerging autism phenotypes and contribute to the heterogeneity in syndrome expression.

The results also revealed sex differences that were independent of the ASD outcome. Specifically, boys in both groups were more advanced than girls in gross motor skills, a finding that is consistent with findings in earlier work on children with ASD[35,36] as well as in typically developing children.[37,38] Furthermore, consistent with previous work,[21,39] boys had a higher activity level than girls.

The current study revealed that despite passing the M-CHAT 6-critical-item criterion, 18-month-old false-negative children show atypical features compared with children in the true-negative group. Importantly, the M-CHAT, ASQ and EAS were completed by parents around the same age of the child, and thus, recall bias and hindsight are unlikely to explain these disparities. At present, it is not clear what contributed to the observed differences among instruments, but several hypotheses can be advanced. First, parents may have difficulties mapping the specific behavioral markers considered in the M-CHAT onto their children's real-life behaviors. They may also have difficulties understanding some of the phenomenology of more specific or rare behaviors related to ASD. Moreover, M-CHAT items do not provide opportunities for graded responses, which might affect how parents weigh their answers. The ASQ gives parents the opportunity to express that the children exhibit skills occasionally

albeit inconsistently, which may allow them to express their concerns and perceptions in a more graded manner. Finally, it is also likely that symptoms of ASD may be expressed differently in early childhood depending on a child's specific level of verbal and nonverbal skill[6] or temperamental characteristics. Another study utilizing a large sample of infants at risk for ASD revealed that at 18 months, children who display more prototypical symptoms of ASD tend to have lower verbal and nonverbal skills than those who are later diagnosed with ASD but show presentation at 18 months is less typical.[6] To date, few ASD-specific screening instruments provide accommodations or modifications for variation in language level, although direct diagnostic measures such as the Autism Diagnostic Observation Schedule, Second Edition consider verbal level when selecting the algorithm items that are most likely to identify children with ASD.[40] However, there are ongoing efforts to develop autism screens that are sensitive to chronological age.[41,42] Similarly, future researchers should examine directly the effects of cognitive and temperament variables on early phenotypic expression of ASD and evaluate if taking these under consideration may improve early detection.

It should be noted that the M-CHAT[7] screen used in the current study has undergone recent revisions, leading to the introduction of the Modified Checklist for Autism in Toddlers Revised With Follow-Up (M-CHAT R/F),[12] which is aimed at decreasing positive screen results while retaining sensitivity. The number of questions in the M-CHAT was decreased by 3, and the 6-critical-item criterion was abandoned such that the M-CHAT R/F now consists of 20 items and has new cutoffs and a recommended follow-up interview to provide greater utility at the diagnostic margins. The newly proposed M-CHAT R/F cutoffs reveal improved ASD detection and diminished rates of false-positives. However, given the lack of a comprehensive prospective follow-up of screen-negative cases, it is not clear whether these changes also led to decreased false-negative rates. Considering that population-based studies that are focused on screening for developmental disorders and incorporate long-term follow-up of all recruits are rare and take a long time to complete, it may be some time before the M-CHAT R/F will be scrutinized in a similar fashion as the original M-CHAT.

We believe that our results contribute, at a fundamental level, to our understanding of early screening for ASD, and we highlight the discrepancy between hard cutoff criteria for autism and the social-communicative, developmental, and temperamental signatures of emerging or subthreshold autism phenotypes. This issue will likely be universal to all parent-directed screening efforts for the foreseeable future. Further research using measures that incorporate levels of verbal and nonverbal skill[6] and temperamental characteristics may prove useful for the development of screening instruments with an improved capacity for identifying children on the autism spectrum in the second year of life. There is also a need to optimize screener design and delivery to fully capitalize on parental knowledge of their children. The results also reveal a unique quality of girls who screen negative but are later diagnosed with ASD, namely diminished shyness or social inhibition. Given that these dimensions are not captured by either the M-CHAT or M-CHAT R/F, this novel finding adds critical knowledge to our understanding of the role of sex in shaping early autistic phenotypes, and we highlight the importance of considering sex differences in early screening and diagnosis. In this study, we also expand state-of-art pediatric practice by emphasizing that when trying to determine if a young child is exhibiting autism symptoms, clinicians should not rely solely on a single instrument but consider parental concerns and draw on other developmental surveillance instruments as well as their clinical judgment.[43] The clinicians also need to be particularly wary about discounting symptoms of social difficulties in girls because they maybe masked by limited shyness or social inhibition.

Limitations of the current study include the lack of concurrent direct measures of verbal and nonverbal developmental levels and absence of data regarding the severity of autism symptoms (eg, Autism Diagnostic Observation Schedule, Second Edition or Autism Diagnostic Interview-Revised). Furthermore, the measures used in the present investigation were restricted to subsets of items from the ASQ and EAS, making it difficult to use cutoffs for clinical concern. Researchers in future replication studies should strive to include full-scale measures. The strengths of the study include the prospective design of the MoBa, the data from an unselected general population, and the ability to examine outcomes of negative screen results across time by identifying children with ASD at later time points through the NPR. Researchers in future prospective population studies should also conduct screening at 24 months of age, according to American Academy of Pediatrics guidelines on screening.

CONCLUSIONS

This is the first study to reveal that despite passing the autism-specific screening at 18 months, both boys and girls who later receive a diagnosis of ASD show delays and atypical features in social, communication, and motor domains. This information was collected via parent report concurrently to the autism-specific screening. These findings reveal that there is a pressing need for enhancing our understanding of how to improve screening instruments, including an evaluation of how well the intended meanings of items are understood and interpreted by parents and how patterns of atypical behavior stratify developmentally by sex. Key future questions involve whether the range of response options provided for each item is sufficiently granular and if new or adapted screening items might improve the capture of the early symptom profiles found here or identify characteristics of lower- and higher-functioning subsets of children.[13] To maximize opportunities for early ascertainment of the broader range of children who will ultimately receive an ASD diagnosis, screening instruments should be refined to improve their capacity for identifying the patterns of deficits that appear to emerge in early life among these later-diagnosed children who escape detection by current screening algorithms.

ABBREVIATIONS

ABC: Autism Birth Cohort
ASD: autism spectrum disorder
ASQ: Ages and Stages Questionnaire
EAS: Emotionality Activity Sociability Temperament Survey
MoBa: Norwegian Mother and Child Cohort Study
M-CHAT: Modified Checklist for Autism in Toddlers
M-CHAT R/F: Modified Checklist for Autism in Toddlers Revised With Follow-Up
NPR: Norwegian Patient Registry
PPV: positive predictive value

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